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VOLUME VII. No. I. JOURNAL OF MYCOLOGY. ISSUED Sept. 10, 1891.

SWEET-POTATO BLACK ROT.

(*Ceratocystis fimbriata*, Ell. & Hals.)

By B. D. HALSTED and D. G. FAIRCHILD.*

(Plates I—III.)

There are several fungous diseases of the sweet potato known under the general term of rots,† but none of them have equaled in destructiveness the one here to be considered, namely, the black rot. It is by no means a new trouble, for many persons who have grown sweet potatoes for fifty years state that they have known of it from boyhood. The common testimony is, however, that it has increased gradually from year to year, until now in some parts of the country the disease is so bad as to be alarming.

In order to obtain definite data as to the prevalence of the black rot in New Jersey, one of the leading sweet potato growing States, a special bulletin of questions was sent to several hundred of the leading growers. From the replies it was evident that in nearly all portions of the State where sweet potatoes were grown they had been troubled with the black rot. Portions of Maryland and Delaware and the large sweet-potato region of Virginia have also more or less of the disease; in fact, so far as our observation goes, no region is entirely exempt. The exact geographical limits of the disease, however, have not been fixed, and whether or not it is strictly American remains to be ascertained.

The chief damage is seen after some months of storage, when the decay spreads rapidly from root to root, sometimes destroying as much as 25 to 30 per cent of the entire crop. Although no accurate data could be gathered in regard to the loss from this disease in distinction from the many other rots, 25 per cent is a low estimate for such seasons as that just passed. The rot in question, which, as is usual with fungous diseases, has been ascribed to wet weather, is caused by an interesting species of fungus; but until the authors took the matter into consideration little was known as to the real cause of the malady, and the fact of its fungous origin, while surmised, was not fully established.

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* Both Mr. Fairchild and Dr. Halsted having done considerable independent work on sweet-potato diseases, it was thought best to combine their results. With this end in view, Mr. Fairchild spent some time in Dr. Halsted's laboratory in New Brunswick, N. J., where the work done in the Department by Mr. Fairchild and in the former place by Dr. Halsted was carefully compared and carried to more complete results. This paper represents a portion of the work.—[B. T. G.]

† Some Fungous Diseases of the Sweet Potato, Bulletin 76, N. J. Experiment Station, November 28, 1890, pp. 32, figures 19.

EXTERNAL APPEARANCE.

The most conspicuous sign of the disease, and the one which distinguishes it from other diseases, occurs upon the potatoes themselves. It consists in the presence of dark, somewhat greenish spots, varying from a quarter of an inch to 4 inches in diameter, sometimes covering the greater part of the root and extending some distance into the tissue. These spots when once seen can not be mistaken, as they are simply sunken areas with distinct margins, like spots burned into the potato with a metal dye which has left the skin uninjured. Should the slightest doubt as to the identity of the disease remain after a superficial examination, the removal of a small portion of the skin exposing the olive-green tissue below would dispel it. Among the sprouts, or young plants grown in hotbeds, the disease manifests itself in dark lines upon the lower portion of the shoot and sometimes of the lower leaves, giving rise to the name of "black shank" among the growers. These dark lines or blotches often appear upon etiolated portions of the stem and are almost black in color. In very severe cases the tip of the sprout wilts and dies. No appearance in the field has so far been observed that would distinguish hills diseased with black rot from those attacked by some other of the numerous rots; but the dark sunken areas on the potato and the black discolorations of the sprouts can scarcely be confused with any other sweet-potato disease.

CHARACTERISTICS OF THE DISEASE.

A microscopic examination of the discolored tissue in the root reveals the fact that the starch-bearing cells have been greatly altered, the healthy portions are characterized by thin-walled cells completely packed with starch, but these have been replaced in the diseased areas by thick-walled, olive-brown ones totally deprived of starch. The thickening of the walls, seen so strikingly upon examination, is due in part to granular incrustations which often assume the form of rounded protuberances. Whether this incrusting matter is anything more than the remains of the protoplasmic contents of the cell, was not determined, but from its irregular appearance this was the natural inference.

Filling the intercellular spaces and often ramifying through the adjoining cells, are the thick-walled, olive-brown hyphæ of the parasite, and the dark color of the diseased portions is due in a measure to them.

While nothing of the nature of haustoria was observed, it was plainly evident that the presence of this abundant mycelium was the cause of the disease, for wherever the threads of the fungus reached, there were darkened cell walls and lifeless contents. No fungous ferment was observed, and it is probable that as with the *Hymenomycetes* described by Hartig* as attacking forest trees, none exists except at a very limited distance from the tips of the hyphæ.

In the intercellular spaces, and often in the cells themselves are found numerous olive bodies, which for want of a better name we have called *olive conidia.* These olive conidia are most abundant in old specimens where the decay has progressed well into the potato, and although occasionally almost wanting, are generally easily observable. Where present in large quantities they give a decided greenish brown tint to the tissue.

Upon the exterior of the diseased area are often found, though sometimes in limited numbers, together with an occasional olive conidium, delicate hyaline spores borne on aërial hyphæ. So far the hyaline spores have not been seen in progress of formation within the tissue of the potato, but upon the blackened sprouts as they are grown in the hotbed they are present in abundance, arising from the tips of elongated hyphæ.

A third form of the fungus shows itself both upon sprout and root in the shape of flask-like pycnidia with elongated beaks or necks fimbriated at the apex. Often the globular bodies of the pycnidia are buried in the tissue of the potato, and only the slender necks are visible above the surface, giving it a bristly appearance.

Where specimens covered with pycnidia are protected from the rains the pycnospores collect in a more or less firmly united mass at the apex of the neck, and the fimbriations seem to serve the purpose of a basket for the mass. The appearance of the fimbriated slender necks and surmounting yellow globules is very characteristic.

Although not certainly connected with the species of fungus causing the black rot there have been found, often in badly diseased specimens, immense numbers of globular sclerotia differing in structure from those of many other species but surrounded by and evidently made up of hyphæ identical with those of this species. These sclerotia were found in all stages of formation and in the last stages in such abundance as to entirely fill the tissue of the diseased potato, causing it to become gray and finally charcoal black.

DESCRIPTION OF CULTURES.

The growth of this parasite upon underground stems composed largely of carbohydrates suggested the idea of cultivating it upon artificial media. In doing this, numerous points of interest were brought out and the structure and development of the fungus were much more easily studied than on the host itself.

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* Die Zersetzungserscheinungen des Holzes 1878, Berlin, Die Lehrbuch der Baumkrankheiten.

A medium composed of a 1 per cent solution of agar-agar in sweet potato broth was the most satisfactory. This was made by adding to 4 grams of agar steeped for 5 hours in 300 cubic centimetres of water 100 cubic centimetres of sweet potato broth. The sweet potato broth was not essentially different from ordinary potato broth, and was made by steeping the slices from one large potato for several hours in enough water to cover them. This medium was used both in the form of plate and slanting test-tube cultures, but proved most satisfactory in the latter on account of the ease with which the tubes were handled.

Besides the sweet potato agar upon which the main study of the fungus was made, several other media were tried. Slices of sweet potato cooked and uncooked in test tubes, similar slices of Irish potato, and *nahrlosung* agar made by adding 2 grams of agar to 200 cubic centimetres of a strong decoction of fresh horse dung, were used, but showed no special points of interest. Ordinary potato broth proved entirely successful and did not reveal the presence, in this species, of sprouting or yeast forms. The fact that sections of the white pine taken from living trees and first sterilized in test tubes by intermittent boiling, grew the parasite in profusion is at least suggestive. Sections from the willow similarly treated failed to nourish the fungus.

Because of the difficulty of obtaining conidia of the fungus with which to start the growth in the hardened culture media the inoculations of sterile media were started from the mycelium itself. Small particles of the diseased tissue were carefully removed with a glass hook from the border line between the healthy and diseased portions of the potato, and sufficiently deep beneath the surface of the skin to render contamination improbable. These particles were at once inserted into the media and almost without exception produced a pure growth of the fungus. Around portions of tissue thus inserted appear in 24 hours the radiating mycelial hyphæ, and in a few days the first form of conidia. After the appearance of the first or hyaline conidia upon the surface of the culture, inoculations with the pure spores were at once made upon the various media above referred to. The cultures grew with great rapidity and maintained their vitality for months. Inoculations made on May 26 from tubes started March 18 show the pycnospores to be still alive.

Van Tieghem cells and hanging drop cultures were employed to ascertain a number of the details of growth and by the use of sweet potato agar in hanging drops on the under side of cover glasses, the growth of certain pycnidia was satisfactorily followed from day to day.

Three days after sowing pure conidia upon sweet potato agar an abundant thallus is formed which has a number of characteristic features.

Mycelium.—The hyphæ rapidly penetrate the artificial substratum, giving it a dark appearance by their presence. They are 2 - 6 μ in diameter, with frequent septa, and filled with oil globules, which give them a guttulate appearance. The globules are present in such quantities that they issue from the broken hyphæ tips under the cover glass and rise to the surface in large numbers. They give the characteristic reaction with osmic acid, are present in natural as well as artificial media, and seem to be more abundant and of larger size in half starved portions than in rapidly growing parts, as noticed by Naegeli* and Cunningham† in various species of fungi.

Simultaneously with the downward growth of the hyphæ into the substratum there rise to the surface specialized branches, which perform the office of sporophores. These long, multiseptate branches, which we may term the primary sporophores, are 60–160μ long by 6–7μ in greatest diameter, generally somewhat fusiform in shape, and with the exception of the lighter colored tips, which reach the surface of the medium, are of the greenish brown color of the remainder of the thallus.

Hyaline, or microconidia.—From the slightly colored tips of these sporophores hyaline conidia are produced immediately after they arrive at the surface of the substratum. These hyaline conidia correspond in a measure to the micro-conidia of *Nectria* and *Hyphomyces*, but owing to the impropriety in the use of the term pointed out by Reinke and Berthold,‡ the term hyaline will be used to avoid ambiguity.

The method of spore formation by which these conidia are produced resembles quite closely that observed by Unger§ in the case of *Graphium penicilloides*, Corda, now called *Chalara Ungeri*, Sacc., and in a less degree that of the new genus *Endoconidium* recently described and figured by Prillieux and Delacroix in the last fascicle of the Bulletin de la Société Mycologique de France.‖ In regard to the spore formation of *Chalara Ungeri*, Sacc., found growing on pine and fir timber in the forests of Austria, Unger remarks: §

> Upon still greater magnification (Fig. 4) it is seen that the brown apices are only the sheaths of fine cylindrical cells from which terminal segments, bound together in a thread-like manner, are abjointed and pushed out. There is no doubt that these latter have the significance of brood cells, although they possess a great similarity to the spores of certain species of *Torula*.

The figure given by Unger represents quite plainly the abjunction of the conidium *within the end* of the hypha in a manner precisely similar to that shown in Plate II, Fig. 1. It differs, however, from the other species of *Chalara* as figured by Saccardo[*] and Corda,[†] in which the spores are represented as being abjointed, not at one but at various points within the sheath-like hyphæ[‡] as in the case of *Sporoschisma mirabile*, B. & Br.;[§] *Bloxamia truncata*, B. & Br.;[||] *Thielavia basicola*, Zopf.;[¶] *Aphanomyces stellatus*, DBy.,[**] and probably, although it has not been possible to examine figures, *Trullula nitidula*, Sacc.[††]

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* Sitzungsberichte der K. Akademie zu München, 1879.

† Quarterly Journal Microscopical Society, XX, 1880.

‡ Reinke and Berthold, Die Zersetzung der Kartoffeln durch Pilze, 1879.

§ Botanische Zeitung, 1847, Nr. 15, T. IV.

‖ Prillieux and Delacroix, *Endoconidium temulentum*, nov. gen. nov. spec. Champignon donnant au seigle des propriétés vénéneuses. Bulletin de la Société Mycologique de France, Tome VII, 2^{e} Fasicule, p. 116.

When the conidiophore has reached the limit of its growth the outer cell wall of the tip and the portion immediately below it ceases growing and becomes slightly tinted olive color like the mycelium. The protoplasm contained between the last septum and the apex continues to grow and ruptures or absorbs the cell wall of the tip, pushing out, seemingly as a naked protuberance of the protoplasmic contents of the cell, but probably clothing itself with an extremely thin membrane, leaving behind the sharply defined broken edge of the conidiophore. After growth has continued for a few minutes and the cylindrical protrusion has attained about the length of the diameter of the sporophore, a septum forms below the mouth of the sporophore and by the further growth of the protoplasmic contents of the mother cell the fully formed gonidium is pushed out from the sporophore only to be followed by a second spore in the same way. Fifty to sixty of these spores are frequently thus shoved out of a single vigorous sporophore, varying from one-half to one hour each in time of appearance. These hyaline conidia remained attached to each other in long chains, often doubling upon themselves in Van Tieghem cell cultures and forming several rows upon the moist underside of the cover glass (Plate II, Fig. 1).

It is surprising that in such a work as that by Dr. Alexander Zalewski, *Ueber Sporenabschnurung und Sporenabfallen bei den Pilzen*, published in 1883,[‡‡] no mention should be made of such a striking modification of the author's second type of spore formation, called *Succedane reihenweise*

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[*] Saccardo, Fungi Italici, Figs. 29, 30, 31, 32, 35.

[†] Corda, Icones Fungorum, T. II, p. 9, Tab. IX, Fig. 43.

[‡] Mr. J. B. Ellis and Dr. H. W. Harkness have kindly allowed the examination of *Chalara acuaria*, C. & E., and *Chalara brachyspora*, Sacc., in which the spores are borne apparently as in *Chalara Ungeri*, Sacc., by abjunction from an elongated mother cell, if the term may properly be applied to such cell with power of continuous conidia formation.

[§] Berkeley, M. J. and Broome, C. E. Notices of British Fungi XL in Annals and Magazine of Natural History, June, 1850, S. 2, Vol. 5, pp. 23, 24 (same in reprint). Reference made to *Graphium penicilloides* l. c., Int. Crypt. Bot., p. 327, Fig. 74; Montaigne, Sylloge Generum Spec. Crypt., 1856, p. 306; Fresenius, Beitr. z. Mykologie, 1852. p. 17, T. VI, Fig. 26, 27, 28.

[||] Ann. Nat. Hist., 1854, p. 468, T. XVI, Fig. 17. Berkeley, Int. Crypt. Bot., p. 327, Fig. 74 b.

[¶] Winter, Die Pilze, Bd. I, Abth. II, p. 44; Zopf, Die Pilze, 1891, Fig. 61, p. 97; Zopf, Über die Wurzelbräune der Lupinen, eine neue Pilzkrankheit, in Zeitschrift für Pflanzenkrankheiten, Band I, Heft 2, 1891, pp. 72–76.

[**] Pringsheim's Jahrbücher, II, p. 170, T. XIX, Figs. 1–3; Linstedt K. Synopsis d. Saprolegniaceen, p. 63.

[††] Saccardo, Michelia, II, p. 285; Sylloge Fungorum, III, p. 732.

[‡‡] Flora, 1883, p. 228; Polish Inaugural Dissertation, 1883. Also in German.

Abschnurung der Sporen auf dem Scheitel der Basidie, especially after the publication in 1847 of such perspicuous figures as those of Unger's above referred to. Although not mentioned by De Bary, this method of spore abjunction is referred to by Zopf in his recent work.

The fully formed spores are thin-walled, hyaline, 16–30 by 4–9μ, bacillary, and sometimes oblong or clavate. They germinate in a few hours in water or nutrient solutions, and quite generally form a protuberance near the medial zone, exactly opposite to the germ hypha, thus giving the germinating spore the form of a cross (Pl. II, Fig. 4). The slender germ hyphæ produce sporophores, often immediately, and these push out from their apices conidia similar in all respects to the original ones (Fig. 4), and the secondary or olive conidia form on more irregular branches (Pl. II, Fig. 5).

Olive or macro conidia.—The second mode of spore formation, which in all essentials resembles the first, takes place, in cultures, following the first, and were it not for its slower movement would be entirely simultaneous with it. Unlike the hyaline spores which are produced upon the surface of the medium, the olive conidia are formed generally deeply buried within the tissues, showing no inclination to rise into the air. The sporophores which bear them consist of simple, septate, branching hyphæ, frequently almost indistinguishable from the primary conidiophores above mentioned, and also from the sterile branches of the mycelium. The mode of spore formation differs from that just described for the hyaline conidia only in tardiness of movement and such other points as the difference in shape of the olive conidia would necessitate; in fact, the two may be said to merge into each other, the primary conidiophores producing spores resembling the olive conidia in shape and *vice versa* (Cf. Pl. II, 2 a, 5 a). Normally, the first olive conidium produced differs from those which follow in being oblong-ovate, while the succeeding ones are globose or elliptical with a small pedicel or extension at the lower extremity (Figs. 5, 6). That these conidia are produced in a manner not wholly in accordance with that described by De Bary * is demonstrated by the fact that the tip of the sporophore is ruptured, as in the formation of the hyaline conidia, upon the formation of the first spore and displays from the beginning of the spore formation (Fig. 8 *a*) until the complete abjunction of the mature spore (Fig. 8*c*) .a distinct somewhat irregular edge or rim, below which is formed the true septum of the conidium (Fig. 8). In older specimens, after four or even five (the maximum number observed) conidia have been pushed out, the protoplasm below the last formed septum often becomes rounded as at Fig. 6, Plate II, clearly demonstrating that the delicate exospore of the conidium is formed within the surrounding end of the sporophore. These olive conidia are 12–19 by 6–13μ, mostly 10–11 by 12–15μ, and in the first stages of their formation are hyaline, thin-walled bodies with more or less evenly granular contents. In the course of 24 hours they become dark colored and coarsely granular, later developing numerous oil globules which react strongly with osmic acid, giving the characteristic brown color. Occasional specimens among hundreds observed manifested a tendency to germinate either in nutrient solutions or water, and those noted sent out long hyaline branching hyphæ. These were not followed to the production of secondary sporidia. From analogy the olive conidia may be expected to serve the purpose of resting spores, possessing thick exospores and being formed largely within the soft tissues of the potato.

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* De Bary, Morph. and Biology of the Fungi, Eng. edition, p. 69–70.

† Zopf, Die Pilze, 1890, p. 97.

Pycnidia.—From a week to 9 days after sowing the hyaline conidia, a third form of fructification makes its appearance, developing with remarkable rapidity and abundance. In its initial stages the pycnidium arises as the swollen and curled or twisted tip of a vegetative hypha, or as a twist or knot in a sporophore between the conidium and its point of union with the main hypha (Plate III, Fig. 9). Although observed to be present in numerous cases, no anastomosing of different hyphæ branches seems necessary. Almost simultaneously with the first curving of the hypha tip, side branches arise which, by their growth and formation of septa, form the coarsely cellular membranaceous wall of the pycnidium. After the globose base of the pycnidium has attained its normal diameter, there arises an elongated ostiolium or beak, composed of slender septate hyphæ placed parallel, side by side, in several ranks about the orifice. By the rapid extension of these hyphæ, a long, hollow neck or beak is formed for the upward passage of the pycnospores. When the neck-forming hyphæ have reached their limit of extension, the tips become gradually tapering and form, upon maturity, long (30–60μ) slender hyaline fimbriations. Both the bulbous portions of the pycnidia and the slender necks vary greatly in size, the former being 96–224 by 96–224μ in diameter, and the latter 395–608μ long by 24–34μ at base and 14–20μ at apex.

Pycnospores.—So far as the extremely fragile nature of the interior permitted observation, the pycnospores are formed by the division of very thin-walled mother cells lining the cavity of the pycnidium. Until means can be devised for removing the difficulties lying in the way of the determination of this point, the exact mode of formation must remain in doubt. The pycnospores are hyaline, globose, or oblong, and are fastened together by a mass of refringent substance tardily soluble in water. When freshly exuded from the tip of the pycnidium, they are 5–9 by 5–9μ; but, upon immersion in water for several hours, they swell greatly, becoming 12–17 by 9–15μ. In culture media, both while remaining closely united in masses and when separated, they germinate profusely, producing upon their frequently anastomosing hyphæ, both hyaline and olive conidia, and finally pycnidia, similar to those in which they are produced. The presence of the gelatinous substance uniting the conidia, manifests itself upon the germination of the spore as a granular film, which assumes (as at Fig 4*b*, Plate III) the form of a delicate ring, often of narrow, lateral extension.

INOCULATIONS.

Healthy potatoes, kept in a moist atmosphere in the laboratory, upon being covered with the hyaline conidia and pycnospores of the fungus, became, in the course of a few weeks, badly diseased with the typical black rot. The fungus is capable of entering the eyes of the potato and is nourished by the small, dead fibrils often connected with the eyes. In inoculations, the diseased portions began in or near the eye. To convince the most skeptical, initials were scratched upon the surface of one potato with a sterile needle, and the surface coated with hyaline conidia in water. In three weeks the initials appeared in typical black-rot lines against the brown back ground.

PROBABLE LIFE HISTORY.

The life cycle of the parasite, although not certainly completed by these different forms, may cover a period of several weeks and perhaps months. The abundant mycelium present in the diseased roots planted in the hotbed for the purpose of obtaining sprouts infects the young shoots as described. This infection may take place either through the medium of spores or by the growth of mycelium from the diseased areas themselves. Diseased sprouts planted in the field produce diseased roots which may spread the disease to other hills either through the soil directly or by means of the numerous fibrils from other plants. These infected areas, although perhaps inconspicuous at first, grow steadily in diameter not being checked by digging, and when the potatoes are stored for keeping continue to grow in the root and at the same time to produce the various forms of spores. These reproductive bodies when supplied with sufficient moisture are capable of infecting, unaided, sound potatoes through their eyes. Thus one diseased potato when stored in a bin of healthy ones is capable of infecting all those in the bin and causing them to rot in a short time.

To what extent the fungus is able to live upon the dead vegetable matter of the soil has not been determined, but from its omnivorous habits numerous substances might be expected to nourish it in an active state. The fact that the parasite grows luxuriantly upon strong *nahrlosung* agar would perhaps indicate its ability to inhabit different stable manures applied to the potato fields, and although no experiments were attempted to show whether a passage through the digestive canal would kill the spores, circumstantial evidence points strongly to the belief that such passage does not destroy all forms.

Ceratocystis fimbriata probably winters not only in the roots used for seed the following spring, but in the soil itself, upon decaying portions of sweet potato roots and other vegetable substances. The sclerotial stage mentioned may be found to compose the principal resting stage of the parasite.

PREVENTIVE MEASURES.

I. The first and most important precaution to be taken in combating the disease is to plant only perfectly healthy seed in the hotbed, even if it is necessary to import such. This preventive measure is most essential, as diseased seed will give diseased sprouts, which in turn will grow a crop of worthless potatoes.

II. The selection of healthy sprouts is plainly necessary in case the fungus gets into the hotbeds, and under no circumstances should diseased plants be put into the field. The test of using copper fungicides in the hotbed has not been made, but from analogy seems to promise assistance. If the fungicide is used the shoots should be kept green with it until pulled.

III. Fields which have become so impregnated by the disease that they refuse to grow profitable crops had best be added to the regular farm rotation. This method will, if continued for several years, allow the accumulated infective material to burn itself out by consuming all available food material in the soil.

IV. Decaying roots and the refuse after digging should be carefully removed from the field and burned, as such débris adds to the food of the parasite.

V. The use of large quantities of barnyard manure probably favors the development of the trouble, since it adds greatly to the decaying vegetable matter of the soil. Where the use of commercial fertilizers can be made to take the place of manure it will certainly be desirable to make the change.

VI. Although no experiments have yet been completed upon the matter, it is probable the spread of the disease in the bin may be checked by dipping the roots in one of the copper mixtures, preferably the ammoniacal solution, before storing for the winter. What effect tobacco smoke or the fumes of sulphur would have in checking the disease in the bins remains to be ascertained.

Experiments are now under way to ascertain, if possible, the effect of the use of the ammoniacal solution of copper carbonate in preventing the disease. Hotbed, field, and bin experiments are in progress, and it is hoped definite results will be obtained.

SUMMARY.

I. The black rot of the sweet potato, both upon young shoots, causing "black shank," and upon mature roots, is caused by the parasitic action of the fungus *Ceratocystis fimbriata*, Ellis and Halsted.

II. Portions of diseased tissue develop, when placed upon various media, abundant growths of the parasitic fungus.

III. Three modes of spore formation are present, two endogenous from the tips of specialized hyphæ, the third from cyst-like bodies. The connection of a sclerotial form, although not demonstrated by culture, is strongly suspected.

IV. Spores grown in cultures are capable of inoculating healthy roots through the broken cuticle or through the eyes.

DESCRIPTION OF PLATES.

PLATE I, *Ceratocystis fimbriata*, Ell. & Hals.

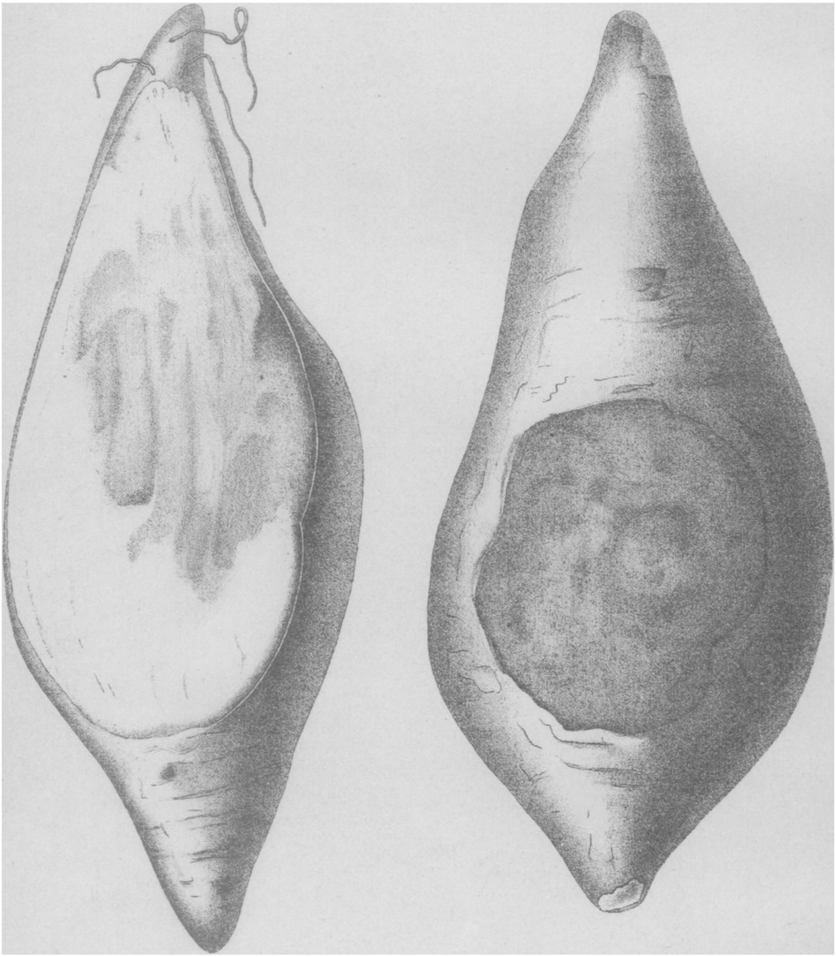
Fig. 1. Sweet Potato showing blackened area, inhabited by the parasite.
2. Cross section of the same.

PLATE II, *Ceratocystis fimbriata*, Ell. & Hals.

Fig. 1. Sporophore of hyaline conidia figured 1 p. m. *1a*, the same figured 1:50 p. m. *1b*, the same at 2:15 p. m. × 550. From test-tube cultures of sweet potato agar-agar.
2. Group of hyaline conidia, showing variations in form from test-tube culture. *2a*, the same from plate culture × 400.
3. Group of hyaline conidia sporophores, showing spore formation × 300. From test-tube cultures.
4. Germinating hyaline conidia from cultures 24–48 hours old in sweet potato agar. *4a*, young germ hypha with hyaline conidium forming. *4b*, hyaline conidium lately expelled from sporophore. *4c*, commencement of sporophore or branch of hypha of germination × 550.
5. Sporophores with olive conidia issuing from tips. *5a*, characteristic primary spore first formed × 550.
6. Sporophore of olive conidium greatly enlarged × 1,500. *a*, ruptured outer wall of sporophore. *b*, protoplasmic contents of mother cell.
7. Olive conidia germinating × 550.
8. Successive stages in formation of olive conidia. *8a*, sporophore and spore figured 12:15 p. m. *8b*, same 2 p. m. *8c*, same 4:35 p. m. *8d*, same 6:25 p. m. *8e*, 9 a. m.
9. Primary growth of mycelial hyphæ from hyaline conidium.

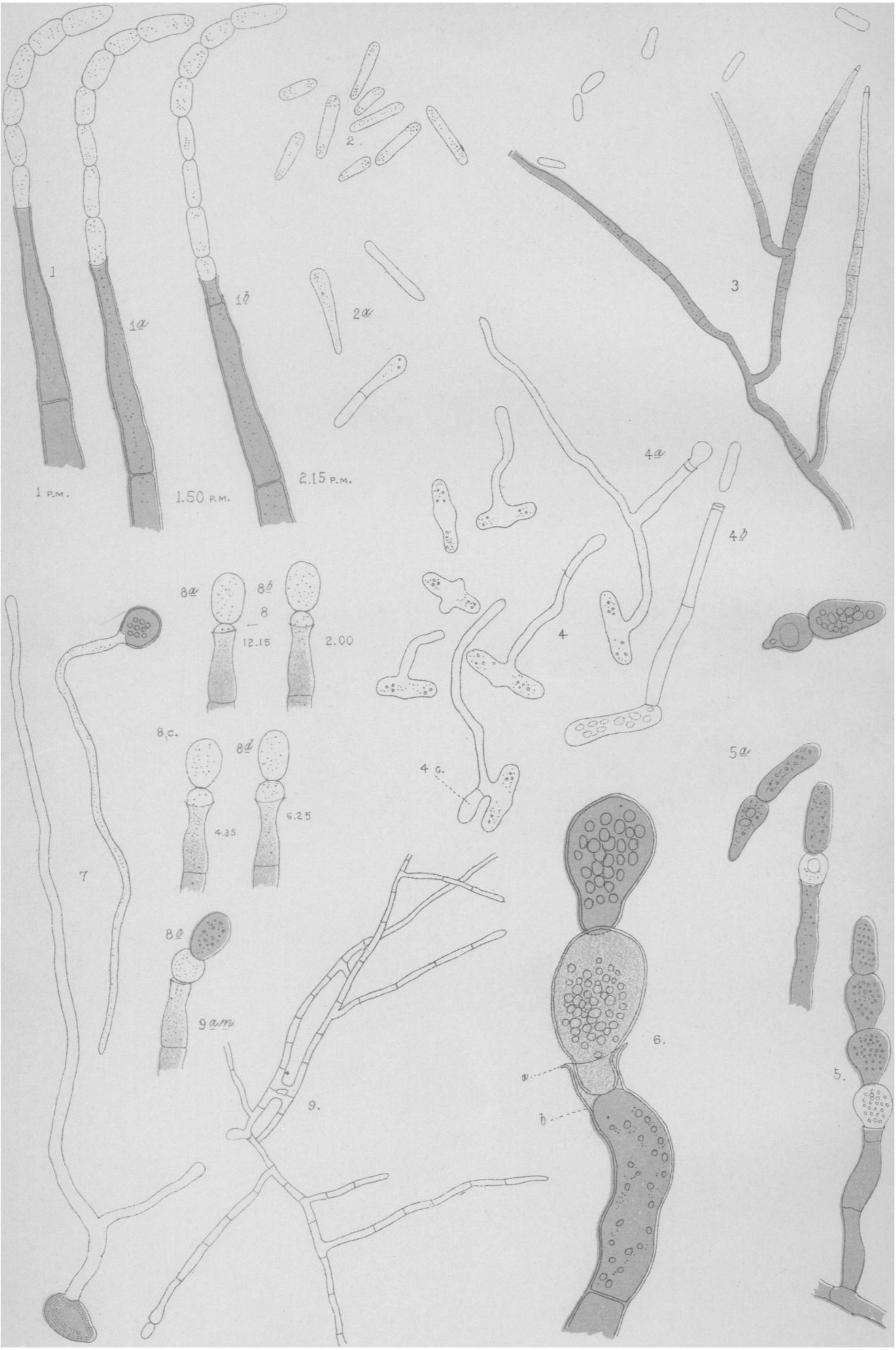
PLATE III, *Ceratocystis fimbriata*, Ell. & Hals.

Fig. 1. Mature pycnidium × 200. *1a*, gelatinous mass of exuded spores.
2. Fimbriate tip of beak or ostiolium × 500.
3. Cross section of pycnidium showing large thin walled cells, previous to spore formation × 300.
4. Gelatinous mass of pycnospores × 550. *4a* isolated spores shortly after immersion in iodine. *4b* pycnospore after 48 hours in sweet potato agar culture. *N*, nucleus; *G*, ring of gelatinous granules.
5. Cross section of pycnidium beak near base × 550.
6. Primary growth of mycelial hyphæ from pycnospore × 200.
7. Anastomosing hyphæ abundant on mycelium from pycnospores and hyaline conidia × 440.
8. Germinating pycnospores. *8a* ring of gelatinous uniting substance. *8b* promycelium in form of a sporophore with hyaline conidium issuing × 550.
9. Primary stage in development of pycnidium × 550.
10. Early stage in development of pycnidium × 550.
11. Immature pycnidium × 400.



HALSTED AND FAIRCHILD ON SWEET POTATO BLACK ROT.

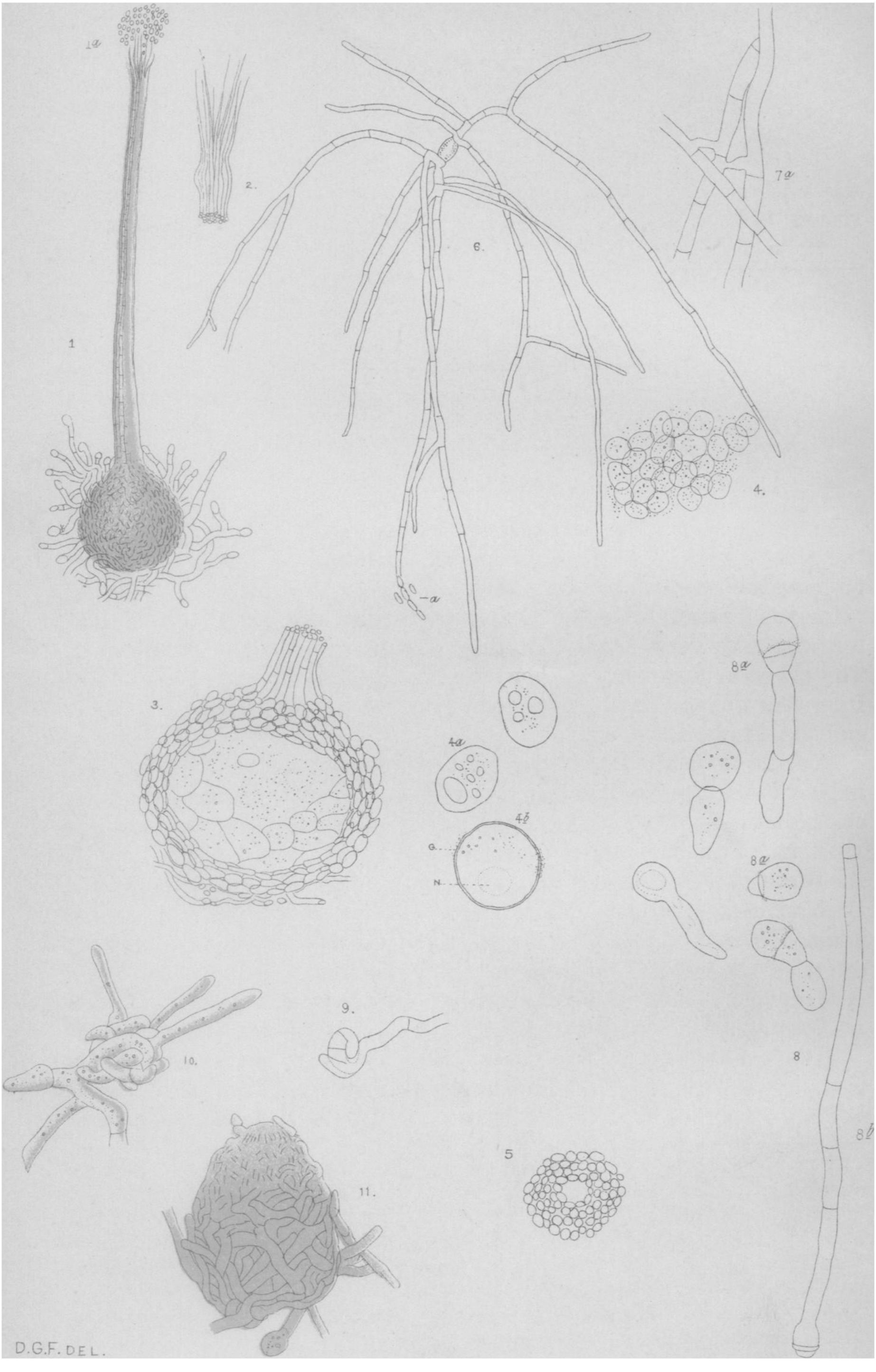
JOURNAL OF MYCOLOGY, U. S. DEPARTMENT OF AGRICULTURE. VOL. VII, PLATE II.



D. G. F. DEL.

HALSTED AND FAIRCHILD ON SWEET POTATO BLACK ROT.

JOURNAL OF MYCOLOGY, U. S. DEPARTMENT OF AGRICULTURE. VOL. VII, PLATE III.



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